COMPARING NEW AND OLD SCENARIOS OF FUTURE CLIMATE CHANGE IMPACTS ON FIRE, CARBON AND VEGETATION DYNAMICS IN EASTERN U.S. FORESTS

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Eastern forests are a tremendous reservoir of natural resources, from diversity of life to clean water and more recently as a means of sequestering carbon in forest, grassland and agricultural ecosystems. The MAPSS team has published future climate impacts simulations on eastern ecosystems using seven future climate scenarios, contributing to several past assessments for the U.S government and the Intergovernmental Panel on Climate Change (IPCC). The IPCC is currently drafting its next assessment using a whole new suite of future climate scenarios. We will present results of changing biogeography, fire dynamics and carbon sequestration in eastern ecosystems using the MAPSS biogeography model and the MC1 dynamic general vegetation model (DGVM) under six new scenarios, comparing and contrasting them to the older scenarios. We are able to make direct comparisons between older and newer versions of the Canadian and Hadley center models, but include a new set of scenarios from an Australian model. The newer scenarios are from three coupled ocean-atmosphere general circulation models (GCM), each of which is operated under two different future trace gas emissions scenarios (relatively high and relatively low CO_2 emissions). The new scenarios differ among themselves, but all forecast some level of increased drought in the different parts of the eastern U.S. The newer version of the Canadian model produces spatially even more extensive drought than it did with the older version. The MC1 model simulated enormous increases in fire in the eastern U.S. under the older Canadian model. Under the newer versions, the extent of those fires will likely increase. However, both the Hadley and Australian scenarios also produce drought in the eastern U.S., but the spatial patterns of drought and fire are quite different.

METHODS

An assessment of North American carbon balance and ecosystem dynamics, including changing vegetation distribution and fire disturbance, in 'natural' ecosystems is underway for input to the fourth global assessment by the Intergovernmental Panel on Climate Change (IPCC). The VINCERA project (Vulnerability and Impacts of North American forests to Climate: Ecosystem Responses and Adaptation) is an intercomparison among three dynamic general vegetation models (DGVMs) running under 6 new future climate scenarios. The MAPSS team (see author list) is contributing output from the MC1 DGVM and the MAPSS biogeography model (http://www.fs.fed.us/pnw/corvallis/mdr/mapss/).

The MAPSS biogeography model and the MC1 dynamic general vegetation model have been extensively used for national and global assessments of the impacts of global warming (e.g. Neilson et al. 1998, Bachelet et al. 2001). See references in these publications for a more full description of the models (MAPSS website). MAPSS simulates the distribution of vegetation types, their relative mixtures of lifeforms (e.g. grass, needleleaf tree, broadleaf tree), the vegetation density (via leaf area) and a full site water balance under an average climate. Typically, simulations are produced for the average climate of 1961-1990 and compared to future climate scenarios, averaged from 2070-2099. However, MAPSS is not capable of providing insights on the temporal dynamics of ecosystems as they make the transitions from current to future conditions. Thus, DGVMs were specifically designed to dynamically simulate combined changes in vegetation distribution, vegetation growth and decline and changing disturbance regimes (fire) under rapid climate change. The MC1 model is a hybrid between MAPSS and the

CENTURY biogeochemistry model, which calculates the growth and decline of vegetation under a varying climate from month to month over years, decades and centuries. Nutrient and water dynamics are simulated along with the climatic control of vegetation processes. MC1 also contains a mechanistic fire model that combines the vegetation type information from the MAPSS side of the model with the vegetation and ecosystem carbon dynamics from the CENTURY side of the model to produce a full description of fuel loadings and characteristics. The fire model determines when, what and how much to burn. Ignition is controlled by three thresholds of fuel loading and fuel moisture characteristics and a deep drought metric, since we are as yet unable to simulate either lightning or human ignition.

The future climate scenarios were produced by three coupled atmosphere-ocean general circulation models (AOGCMs), each using two different future trace gas emissions scenarios, A2 and B2 (SRES, an IPCC Special Report on Emissions Scenarios). The GCM scenarios are from the Canadian Climate Centre (CGCM2), the Hadley Centre (HADCM3) and Australia (CSIRO-MK2). The three DGVMs are MC1, IBIS and SDGVM. All of the scenarios are near the warmer end of the IPCC's projected future temperature range with average temperature increases over North America by the end of the 21st century ranging from over 6^{o} to nearly 9^{o} C (Figure 1).

RESULTS

The previous national and global assessments produced a hypothesis sometimes referred to as the 'early greenup, later browndown' hypothesis (EGLB). The gist of the hypothesis is that with a relatively small amount of climate warming vegetation is benefited by increases in precipitation, increases in the length of the growing season and some benefit from increased water use efficiency due to elevated CO_2 concentrations. Simulations over the globe and specifically over the U.S. produced a 'greening earth', which does appear to be occurring today. However, with continued warming, the exponential effects of increasing temperature on evapotranspiration overwhelm the beneficial effects producing a rapid and potentially catastrophic dieback, likely mediated by drought, infestations and fire. Thus, drought-induced forest dieback can occur through two primary mechanisms, a lack of precipitation, or an increase in temperature, being most extreme if both occur. The EGLB hypothesis was applied globally, but certain regions appeared to be most sensitive

The eastern U.S. was highlighted in the previous assessments as being especially sensitive to both mechanisms. The Southeast appears to be sensitive to losses of precipitation, likely due to changes in the Bermuda High circulation dynamics. That the SE is sensitive to losses in precipitation should not be surprising, given its location in the subtropical climate zone that produces many of the world's extreme deserts. However, the mid-Atlantic states of the temperate deciduous forest and zones up through the Great Lakes area are also sensitive to drought, but more via the mechanism of increased temperature under the future scenarios, even with some increases in precipitation.

Using 7 future climate scenarios, Bachelet et al. (2001) found that for each degree of temperature increase 17% of the area of U.S. forests would be placed under drought stress, primarily in the Southeast. Under the hotter scenarios the Southeastern U.S. was sensitive to conversion to savanna or grassland due to drought followed by catastrophic fire over large spatial extents. The simulations suggested that such drought and fire conversions could begin within the next few decades.

The simulations under the 6 new scenarios using both MAPSS and MC1 are largely consistent with the earlier results with respect to the sensitivity of eastern U.S. forests to drought, likely infestation (not simulated) and fire (Figures 2, 3). As of this writing, the MC1 simulations are still undergoing analyses, however, preliminary results suggest a process of massive drought stress due to increasing temperatures, even in areas with increasing precipitation, followed by extensive forest dieback and fires converting large areas of the eastern forests to tree savannas, woodlands and grasslands. Under all scenarios, eastern forests are significantly reduced in area with the most extreme scenario converting perhaps 70 – 80% (visual estimate) of the eastern forests to savannas and grasslands from the Gulf coast to the Lake States. The process of dieback and type conversion does not proceed from the forest-grassland ecotone, but instead occurs almost instantaneously over vast areas.

DISCUSSION AND CONCLUSIONS

Simulations of changing vegetation distribution, carbon dynamics and fire disturbance over North America have been completed for six new future climate scenarios from three General Circulation Models under two different future trace gas emissions scenarios. The scenarios have been simulated using both the 'static' biogeography model MAPSS for the period 2070-2099 and using the dynamic general vegetation model, MC1. The two models produce nearly identical results for the end of the 21^{st} century, but MC1 provides considerable detail on the trajectory of change.

Both models produce a major dieback in the eastern deciduous forest, mediated by drought and followed by fire. Neither model simulates the impacts of insects, but the results suggest that infestation could also play a major role in type conversion. The results support the 'early greenup, later browndown' hypothesis where slight warming should cause vegetation to grow more, but that a large amount of warming should produce a drought induced dieback from drastically increased evapotranspiration. The simulations suggest that productivity has been increasing over North America for most of the 20^{th} century, but that the 'dieback' phase could begin at nearly any time over the next several decades.

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Ronald P. Neilson, Presenter

Ron Neilson is a BioClimatologist with the USDA Forest Service, Pacific Northwest Research Station and a Professor (Courtesy) with the Department of Botany and Plant Pathology and the Department of Forest Science at Oregon State University. Dr. Neilson has focused on the theory, mechanisms and simulation of vegetation distribution for nearly three decades. He received the Cooper Award from the Ecological Society of America for his research on oak distribution in the Rocky Mountain region. The MAPSS biogeography model and MC1 dynamic general vegetation model have contributed to national and global assessments by the Intergovernmental Panel on Climate Change (IPCC) and the U.S. Global Change Research. Dr. Neilson was the lead author for the Forest sector for the IPCC's special report on *The Regional Impacts of Climate Change* and the convening lead author for an Annex to the Special Report on simulations of global vegetation re-distribution under climate change. His current work extends into Earth System Modeling, Landscape System Modeling and large-scale fire forecasting. Dr. Neilson received the Forest Service Chief's 1999 Honor Award for Superior Science and the USDA Secretary's Honor Award for Superior Service in 2003. He received a BA from the University of Oregon, an MS from Portland State University, and a Ph.D. from the University of Utah.

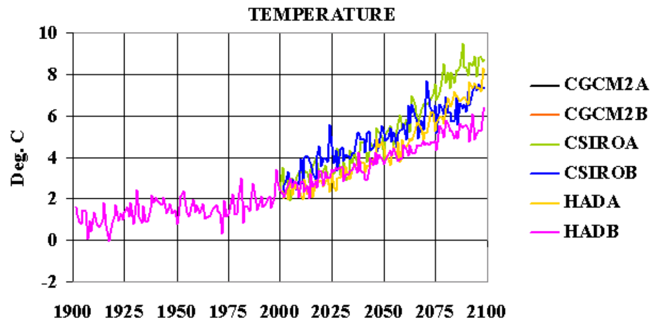

Figure 1. Observed historical and simulated future temperature trends over North America.

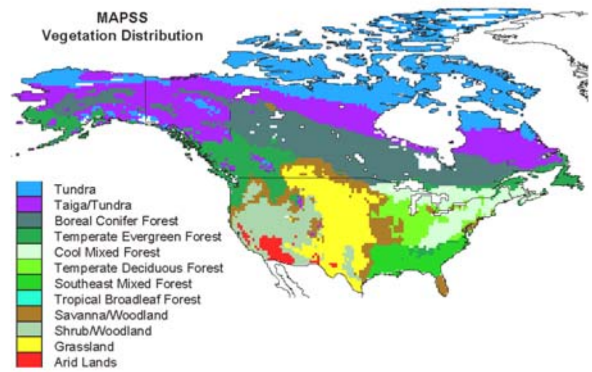

Figure 2. Simulated 1961-1990 'natural' vegetation distribution (MAPSS).

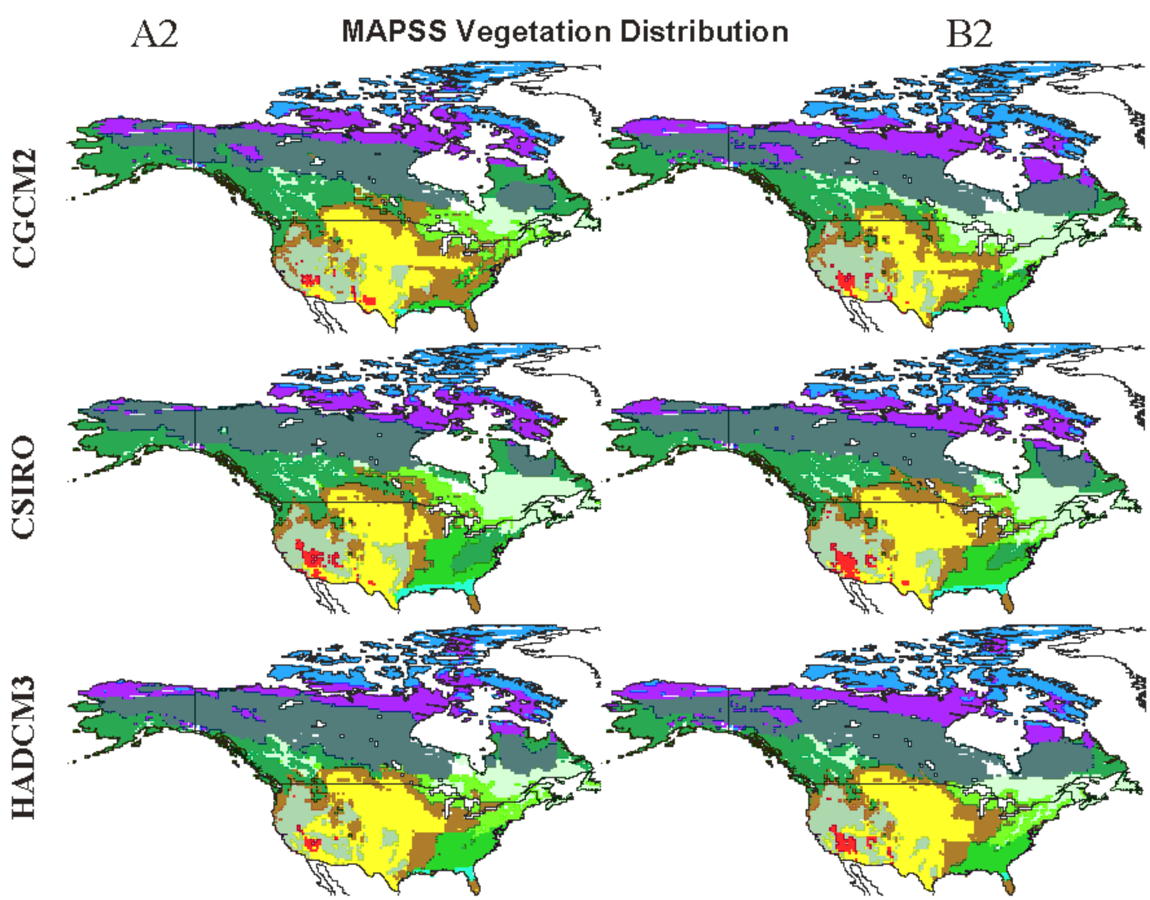

Figure 3. Simulated 2070 - 2099 'natural' vegetation distribution (MAPSS).